POWER SYSTEM DESIGN FOR SOLAR CAR

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature

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ABSTRACT

The solar car power system consists of three main subsystems which are the solar array, battery management and lastly, battery pack. It is arguably the most essential system of a solar car since it generates power for the car thus vastly influences the functionality of the car itself. This project was carried out to design a solar car power system that is feasible, cost effective and in compliance with the rules and regulations of the 2011 World Solar Challenge (WSC). The main objective of this project was to design an electrical layout of a solar car power system with components that are properly selected as well as carrying out analysis to determine the practicality and compatibilty of the design. The design of the power system was divided into four levels which were the selection of subsystems' mian components, design of the subsystems, the conditioning of the power system and finally, the design of the overall power system itself. These steps involved drawing of design, design calculations and analysis of compatibilty within the power system. The drawings involved in the design of the system were done via Solidworks 2010 and SmartDraw 2010 softwares. The finalized design delivered a power system that could generate a maximum power of 837.6W through its solar array designed by tabbed monocrystalline solar cells. The power generated would be stored in a battery pack which consists of five VRLA batteries with a combined power capacity of 6.4kWh. A buck type maximum power point tracker configures the input from the solar array to the battery pack. Motor controller of the actuation system would configure the power system to continuously supply 1kW to the motor. It is calculated that in ideal conditions, the power system can continously power the motor for at least 11.99 hours which is already sufficient for a day of solar racing. The results and discussion concluded that the design of the solar car power system is feasible to be implemented and is considerably cost effective, within the financial prowess of the university. Through proper justifications, the design is also proven to be compatible within the system itself. For further improvements in the future, this project should be conducted with a greater budget so that rather than coming up with a conceptual design, a fabrication or at least a better form of design simulation can be done. Besides that, with greater budget, better components that are more costly are then affordable.

ABSTRAK

Sistem kuasa kereta solar terdiri daripada tiga subsistem utama iaitu modul solar, pengatur cas dan sistem bateri. Ia boleh dianggap sebagai sistem yang paling penting bagi sesebuah kereta solar memandangkan ia menjana kuasa untuk kegunaan kereta tersebut dan oleh sebab itu, ia menentukan sejauh mana sesebuah kereta solar dapat berfungsi. Projek ini dilaksanakan untuk mereka sebuah sistem kuasa kereta solar yang praktikal, kos efektif dan mematuhi peraturan pertandingan World Solar Challenge 2011. Objektif utama projek ini adalah untuk mereka sebuah plan elektrikal bagi sistem kuasa kereta solar dengan menggunakan komponen-komponen yang dipilih secara teliti serta menjalankan analisis untuk menetukan kewajaran dan kesinambungan rekaan tersebut. Rekaan sistem kuasa ini dibahagikan kepada empat peringkat iaitu pemilihan komponen utama bagi setiap subsistem, rekaan subsistem, pemantapan sistem dan akhir sekali, rekaan sistem kuasa secara menyeluruh. Proses ini melibatkan lakaran rekaan, pengiraan serta analisis bagi menetukan kesinambungan sistem. Lakaran bagi rekaan sistem kuasa ini dihasilkan dengan menggunakan Solidworks 2010 dan SmartDraw 2010. Rekaan yang terhasil memberikan sebuah sistem kuasa yang mampu menjana kuasa maksimum sebanyak 873.6W melalui modul solarnya yang direka dengan menggunkan sel solar monokristalin. Tenaga yang terhasil disimpan di dalam sistem bateri yang terdiri daripada lima bateri VRLA dengan kapasiti 6.4kWh. Cas daripada modul solar ke sistem bateri diatur dengan menggunakan pengatur cas injak turun. Pengatur motor melaraskan agar 1kW kuasa dibekalkan secara berterusan ke motor. Maka, melalui pengiraan, di bawah keadaan sempurna, didapati bahawa motor boleh berfungsi secara berterusan selama sekurang-kurangnya 11.99 jam iaitu jangka masa yang mencukupi untuk sehari perlumbaan. Akhir sekali dapat disimpulkan bahawa sistem kuasa yang direka adalah praktikal untuk dilaksanakan serta didapati kos efektif iaitu setimpal dengan peruntukan universiti. Di samping itu, sistem yang dihasilkan juga terbukti akan kesinambungannya. Projek boleh ditambahbaikkan pada masa akan datang sekiranya dana yang secukupnya dapat diperuntukkan. Dengan itu, rekaan dapat dihasilkan bukan sahaja dari segi konseptual tetapi juga dari segi pembuatan atau sekurang-kurangnya simulasi yang lebih bersesuaian. Selain itu, komponen-komponen yang lebih baik juga mampu digunakan sekiranya dana bagi projek mencukupi.

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LIST OF SYMBOLS

A	Area
m	mass
V	Voltage
I	Current
P	Power
N	Number of Solar Cell / Panel / Module / Battery
N_{max}	Maximum Number of Solar Cell / Panel / Battery
V_{mp}	Maximum Voltage
I_{mp}	Maximum Current
t	Time
G	Solar Radiation
T	Temperature

LIST OF ABBREVIATIONS

AC	Alternate Current
Ag-Zn	Silver Zinc
$LiFePO_4$	Lithium Iron Phosphate
Li-ion	Lithium Ion
Li-polymer	Lithium Polymer
MPPT	Maximum Power Point Tracker
Ni-Fe	Nickel Iron
NiMH	Nickel Metal Hydride
Ni-Zn	Nickel Zinc
Pb-acid	Plumbum Acid / Lead Acid
PV	Photovoltaic
PVC	PolyVinyl Chloride
SWD	Switching Duty
VRLA	Valve Regulated Lead Acid
WSC	World Solar Challenge

CHAPTER 1

INTRODUCTION

1.0 Introduction

The global energy crisis started with the predicted shortage of crude oil. Due to insecurities regarding the future availability of petroleum, the main form of non-renewable energy, the whole world are looking for other energy alternatives. Renewable energy such as wind, solar, tidal, wave and biomass is definitely considered as a fraction of the remedy. Thus, more and more investment is pumped into the development of renewable energy (Anthony Hilliard et.al. 2008).

Nowadays, solar energy covers only 0.5% of the world's energy consumption. However, its significance as an energy source is predicted to further increase in the future. Solar energy is said to have a great potential in becoming one the main types of energy in the world (Rosaidi, 2009). One of the efforts done in order to fulfill the potential of solar energy is via integrating the use of solar energy with cars. These cars are called solar cars. Since its introduction, various solar cars were built and tested fo either racing or demonstrative purposes (Ivan Arsie et. al. 2006) In the year 1983, Hans Tholstrup and Larry Perkins crossed Australia in their solar car named the Quiet Achiever. From that point, the solar car technology continuously received encouragement thus developed and matured through racing events such as the World Solar Challenge. It is because of that, up until now, existing solar cars clearly inherit a race-bred history (A.Simpson et. al. 2002).

However, despite these achievements, solar cars are still some way off from conventional cars due to limitations such as inconsistency of solar cource availability and the need of minimizing weight, friction and aerodynamic losses. These limitations are basically among the aspects that need to be taken into consideration while designing a solar car. Besides, these limitations also outline the challenges which lie in the building of a solar car (Ivan Arsie et. al. 2006).

1.1 Problem Statement

One of the biggest hurdles faced by solar cars is the limitations posed by its power system. This is because photovoltaic (PV) technology is known to be expensive and the availability of solar energy vigorously depends on the weather and surroundings. Hence, the power system is arguably the most critical aspect of a solar car. A solar car power system has the main goal of harnessing ample energy to operate the vehicle. Many aspects has to be considered in the designing process of a solar car power system such as feasibilty of design, cost as well as safety measures. This study tries to deliver a proper solar car power system design that is cost effective, in compliance to the rules and regulations of the 2011 World Solar Challenge and most importantly, practical and compatible for use in solar vehicles.

1.2 Objectives

There are three objectives identified in this particular project. First of all is to design the electrical layout of a solar car power system from the solar array to the battery pack. The second objective is to select the suitable components that are to be used in the design of the power system. Last but not least, this project also requires analysis of the various aspects of the solar car power system with regards to the compatibility within itself as well as its practicality in production.

1.3 Scope of Study

The project scope is essential as it draws a guideline to ensure the project is conducted within its intended boundaries and remains in the right direction to achieve its objectives. There are several criterias in which the scope of this project covers. First of all, the type of solar cells, maximum power point tracker and batteries for the design of the power system is to be determined. The component selected must be of the ones available in the market. The solar car power system is to be designed according to the technical regulations of the 2011 World Solar Challenge. SmartDraw 2010 software is used to draw electrical circuits and diagrams of the power system design. As for components such as the battery box and the array stand, they are to be designed using Solidworks 2010.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter provides an academic review of facets related to solar car power system. It starts with the history of solar energy and the fundamentals of a photovoltaic system. Furthermore, it discusses the existing types of photovoltaic cells, maximum power point trackers as well as batteries in relevance to the topic of the study. The distinctions, advantages and disadvantages of each types are revealed.

2.1 History of Solar Energy

Solar energy exploration is said to have started a long time ago. Ancient Greeks and Romans saw great benefit in passive solar design, which is the use of architecture to make use of the sun’s capacity to light and heat indoor spaces. This art was further advanced by the Romans who covered south facing building openings with glass or mica to hold in the heat of the winter sun. Through calculated use of the sun’s energy, Greeks and Romans offset the need to burn wood that was often in short supply. In 1861, a steam engine powered entirely by the sun was developed (T.Mohd, 2009).

Solar energy continued to attract European scientists through the 19th century. Scientists developed large cone-shaped collectors that could boil ammonia to perform work such as locomotion and refrigeration. There was also a point when France and England hoped that solar energy could power the operations of their colonies in Africa and East Asia. Moving on, solar power could boast few major gains through the first half of the 20th century. In fact, Albert Einstein was even awarded 1921 Nobel Prize in physics for his research on the photoelectric effect. The photoelectric effect is a phenomenon referring to the generation of electricity through solar cells (T.Mohd, 2009).

Back then in the 1950s, solar photovoltaic (PV) cells were far from economically practical. The hope in the 1970s was that through massive investment in subsidies and research, solar photovoltaic costs could drop sharply and eventually become competitive with fossil fuels. By the 1990s, cost of solar energy dropped as predicted but costs of fossil fuels had also dropped. Thus the idea of solar technology being economically practical did not change quite as much. However, huge PV market growth in Japan and Germany from the 1990s to the present has reenergized the solar industry. Such progress has been creating economies of scale, thus steadily lowering costs. The PV market is currently growing at a blistering 30 percent per year, with the promise of continually decreasing costs (T.Mohd, 2009).

2.2 Photovoltaic System

Photovoltaic (PV) is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity. Due to the growing demand for clean sources of energy, the manufacturer of solar cells and photovoltaic arrays has expanded dramatically in recent years. Photovoltaic production has been doubling every two years, making it the world's fastest-growing energy technology (Suhaifiza, 2009). Solar energy has been used around the world for powering numerous applications. It works by converting energy from the sunlight directly into electricity (DC). The smallest part of a photovoltaic panel is called photovoltaic cell. Multiple solar or photovoltaic cells are connected to form a solar module and combination of solar module by series or parallel is called the solar array (Rosaidi, 2009).

The electricity from the solar cells is stored in the battery for immediate or later use. The role of the charge controller is to regulate the voltage and current from the solar cells before it is stored in the battery. It monitors the condition of the battery state of charge and protects the battery from being over-charged. The charge controller will also protect the battery from discharging below its lowest acceptable voltage. Where required, an inverter is used to change the Direct Current (DC) to Alternating Current (AC) to power most AC appliances (Rosaidi, 2009).

2.3 The Photovoltaic Effect

The photovoltaic effect is a phenomenon that converts the sun's electromagnetic energy directly to electricity. A junction of two dissimilar semiconductor materials is very effective in producing this phenomenon (Batcheller, 1993). As seen in Figure 2.1, solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor, usually silicon. They are specially created to form an electrical field, positive on one side and negative on the other. When solar energy in the from of photons hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material creating electron-hole pairs. If electrical conductors are then attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current, I_L in which in this case is known as photocurrent (Hafiez, 2009).

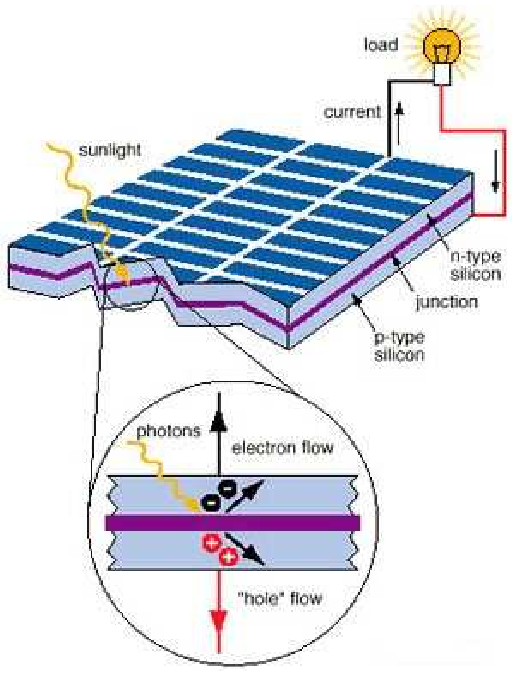

Figure 2.1: Photovoltaic effect

Source: Suhaifiza, (2009)

2.4 Types of Photovoltaic Cells

Solar cells are made up of various semiconductor materials, which become electrically conductive when supplied with heat or light. The majority of solar cells produced are composed of Silicon (Si) which exist in sufficient quantities and do not add any burden on the environment (Hafiez, 2009). The main purpose in the research and development of photovoltaic cells is to improve the energy conversion efficiency of solar cells as well as other related parameters in order to reduce the commercial cost of solar cells and modules. The continuous efforts of producing high efficiency solar cells at lower cost have helped to produce various photovoltaic technologies that are available in today's market. The three main classifications of solar cells are crystalline silicon, thin-film and multi-junction (Irwan, 2008).

2.4.1 Crystalline Silicon

Silicon is the most used type of semiconductor in the fabrication of solar cells. The two common types of solar cells that fall into this category are Monocrystalline Silicon and Polycrystalline Silicon (Irwan, 2008)

Monocrystalline Silicon

These cells are made from very pure monocrystalline silicon. The silicon has a single and continuous crystal lattice structure with almost no defects or impurities. A monocrystalline silicon solar panel can be seen as shown in Figure 2.2. Monocrystalline cells have an approximate efficiency of up to 18%. It is the first type of solar cell to be developed commercially. The manufacturing process required to produce Monocrystalline is complicated, thus causing in slightly higher costs than other technologies (Irwan, 2008) (William, 1992) (T.Mohd, 2009)

Figure 2.2: Monocrystalline silicon solar panel

Source: Irwan, (2008)

Polycrystalline Silicon

This cell, as shown in Figure 2.3, is produced using numerous grains of monocrystalline silicon. Polycrystalline, also known as multicrystalline cells, are cheaper to produce than monocrystalline ones, due to the simpler manufacturing process. However, they tend to be slightly less efficient, with average efficiencies of around 13%. Similar to monocrystalline cells, polycrystalline cells have long life-span (Irwan, 2008) (William, 1992) (T.Mohd, 2009).

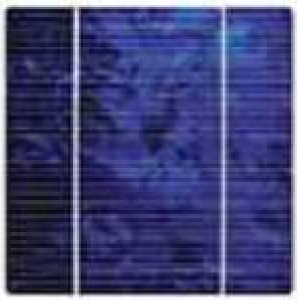

Figure 2.3: Polycrystalline silicon solar cell

Source: Irwan, (2008)

2.4.2 Thin Film

Thin film solar cells such as Amorphous Silicon, Copper Indium diselenide and Cadmium Telluride has relatively low efficiency of within the range of 6% to 12%. The advantages of thin film solar cells are their lightweight and their low cost due to less complicated manufacturing processes. Their low cost makes them ideally suited for many applications where high efficiency is not required and low cost is important. Examples of applications that use thin film cells are toys, calculators and watches (Irwan, 2008).

2.4.3 Multi-Juction Cell

Multi-junction cells are solar cells that are developed for very high efficiency. Given its very high efficiency, multi-junction solar cells are very expensive and currently, are only feasible for high cost applications such as in the Aerospace industry (Irwan, 2008).

2.5 Effects of Radiation and Temperature on Photovoltaic Cells

Output power produce by solar array depends on solar irradiation and temperature. It influences the I-V and P-V characteristics.

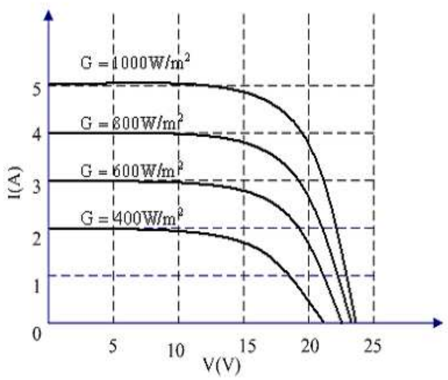

Figure 2.4: The effect of solar radiation, G on the I-V characteristic curve

Source: Rosaidi, (2009)

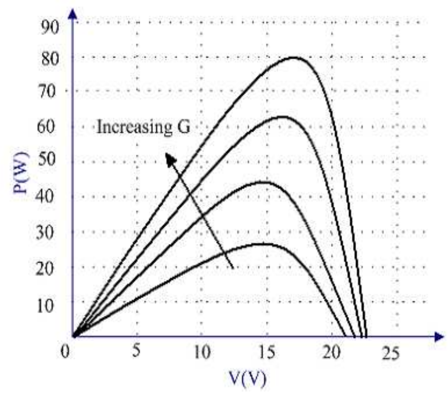

Figure 2.5: The effect of solar radiation, G on the P-V characteristic curve

Source: Rosaidi, (2009)

Both Figure 2.4 and Figure 2.5 above demonstrate that the short circuit current of a solar array is directly proportional to the solar radiation. This means that the greater the solar radiation is, the bigger the output current will be hence producing higher maximum output power (Rosaidi, 2009).

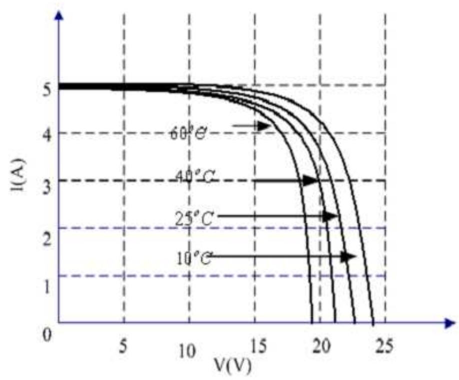

Figure 2.6: The effect of temperature, T on the I-V characteristic curve

Source: Rosaidi, (2009)